Improved Limit on the Electron Capture Decay Branch of ^{176}Lu*

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The long-lived naturally occurring nuclide ^{176}Lu ($J^{\pi} = 7^{-}$) β^{-} decays to levels in ^{176}Hf with a half-life of (4.00 $\pm$ 0.22)x10^{10} years (Ref. 1). However, ^{176}Lu is also unstable with respect to electron-capture decay to ^{176}Yb. The Q_{EC} for decay to the ^{176}Yb ground state is 106.2 keV (Ref. 2). Thus, EC decays to both the $J^{\pi} = 0^{+}$ ground state and $J^{\pi} = 2^{+}$ 82-keV first excited state of ^{176}Yb are possible. These EC decay branches would be 7th and 5th forbidden transitions, respectively, and thus are expected to be negligibly small. The published limit on the EC decay branch of ^{176}Lu of < 10% was reported by Arnold in his study of the decay of ^{176}Lu (Ref. 3). This limit was derived from a search for Yb K x-rays that would be produced by the EC decay of ^{176}Lu. Because of the recent problems encountered in using the ^{176}Lu/^{176}Hf chronometer, it was felt that a new search for the EC decay of ^{176}Lu was warranted.

Two plastic bottles, each containing 5 grams of $LuCl_3 \cdot 6H_2O$ were placed against the endcap of a 110 cm^3 high-purity germanium detector. X- and γ-ray data from approximately 20 – 800 keV were acquired in 4096 channels for a period of 65 hours using an ORTEC PC-based acquisition system. The Hf K x rays and the 88-, 202-, 307-, and 401-keV γ rays produced by the β^{-} decay of ^{176}Lu were clearly observed. However, no evidence of Yb K x rays or 82-keV γ rays was seen.

All of the β^{-} decays of ^{176}Lu eventually produce transitions through the 88-keV level in ^{176}Hf. Thus, in order to establish a limit on the EC decay branch to the 82-keV level in ^{176}Yb, we determined the net area of the 88-keV peak and the gross area of an equal width energy interval centered on 82 keV in the spectrum obtained from the Lu_2O_3 sample. The net area of the 88-keV peak was determined to be N_{88} = 79111 $\pm$ 534 counts, while the gross area of the 82-keV region was found to be 46623 $\pm$ 216 counts. Since no peak was observed at 82 keV, we multiplied the gross area of this interval by 2 and then took the square root to obtain a 1σ upper limit on the net area of 82-keV peak, N_{82} < 305. Both the 88-keV level in ^{176}Hf and the 82-keV level in ^{176}Yb decay mainly by internal conversion rather than by gamma-ray emission. The total conversion coefficient, α_T for the 88-keV transition is 5.914 and that for the 82 keV transition is 7.125 (Ref. 4). Thus, the limit we can establish on the branch for the EC decay of ^{176}Lu to the 82-keV level in ^{176}Yb is B_{82} < 0.0045 (or 0.45%).

The β^{-} decay of ^{176}Lu produces Hf x rays through the internal conversion decays of the 998-, 597-, 290-, and 88-keV levels in ^{176}Hf. Hf K_{α} x rays are emitted in 25.4% of all ^{176}Lu beta decays (Ref. 5). Yb K_{α} x rays would be produced in 38.4% of all ground state to ground state EC decays of ^{176}Lu (Refs. 5,6). Thus in order to establish a limit on the EC decay of ^{176}Lu to the ground state of ^{176}Yb, we determined the net area of the Hf K_{α} x-ray doublet, N_{Hf} = 331382 $\pm$ 576, and established an upper limit on the net area of a possible Yb K_{α} x-ray peak, N_{Yb}, in the spectrum obtained from the Lu_2O_3 sample. To establish this upper limit, we added a scaled version of the spectrum obtained from the fluorescence of the Yb_2O_3 sample to the spectrum obtained from counting the Lu_2O_3 sample. We then compared the resulting sum to the original Lu spectrum to see if we could observed "shoulders" on the low-energy sides of the Hf x-ray peaks that would be caused by the presence of the Yb x rays. In the Yb_2O_3 fluorescence spectrum N_{Yb} = 18065 $\pm$ 247. Our limit on the scale factor at which we could still detect the Yb x rays in the summed spectrum was 0.10. Thus our 1σ upper limit on the EC decay of ^{176}Lu to the ^{176}Yb ground state is:
B_{gs} < [0.10 x 18065 x 0.254] / [331382 x 0.384] = 0.0036 (or 0.36%). These limits are more than a factor of 20 better than the only previously published limit on the EC decay of ^{176}Lu.

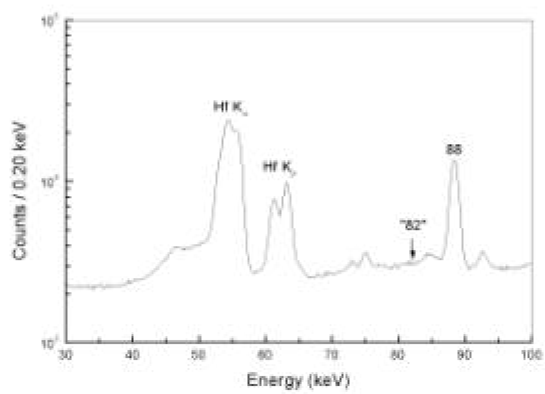

Figure 1. Expanded region of the spectrum observed from the 10-g sample of $LuCl_3$. The expected position of the 82-keV γ ray from the possible EC decay of ^{176}Lu is indicated.

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